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Synthesis and thermoluminescence properties of gamma ray irradiated $NaCl:Dy^{3+}$ phosphor

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Abstract

The synthesis and thermoluminescence (TL) properties of γ-irradiated $NaCl:Dy^{3+}$ phosphors are reported in this paper. The $NaCl:Dy^{3+}$ phosphors of different concentrations of Dy^{3+} doped in NaCl host are prepared by a wet chemical method. TL of all phosphors has been recorded for different γ-doses. The nature of variations of peak TL intensities is found to be sublinear with γ-irradiation dose and with the concentrations (0.05-0.5 mol%) of added Dy^{3+} in all the samples. The dose response curve is linear upto 0.6 kGy. Minimum fading is observed in the prepared sample.

Keywords: Thermoluminescence (TL), colour centres and $NaCl:Dy^{3+}$ phosphor

INTRODUCTION

Thermoluminescence (TL) in alkali halides has been studied for more than sixty years. It is known that the emission is due to radiative recombination of halogen atoms thermally released from the interstitial positions with F centres [1]. In most of the experiments, irradiated alkali halides have been used, and while analyzing the thermoluminescence data it has most often been assumed that the irradiation has created equal number of recombination centres and filled traps. Colour centres in alkali halides have now been studied for last many years. It is known that the electrolytic ally coloration produced in potassium halides lost within a day [2]. The colour centres have mostly been studied in single crystals, while applications such as dosimetry of the ionizing radiation using thermoluminescence (TL) more often involves measurements on powders. It is generally believed that the mechanism of colour centres production is similar for single crystals and microcrystalline powder. Colour centres production by γ-irradiation in NaCl, KCl and KBr is reported by Deshmukh and et. al. in crystal and microcrystalline powder [3]. Recently, Bangaru and co-workers [4, 5] also reported enhanced luminescent properties and TL studies in alkali halides by doping rare earth materials. The study of luminescence properties in alkali halides, to find possible dosimetric material is a challenging task in the development of radiation dosimetry.

In this paper, TL of gamma ray-irradiated $NaCl:Dy^{3+}$ (0.05–0.5mol%) materials are studied for possible applications of dosimetric materials.

EXPERIMENTAL

All phosphors containing different concentrations of Dy^{3+} (0.05-0.5 mol%) were prepared by wet chemical method. For preparation of $NaCl:Dy^{3+}$ the required concentration of Dy^{3+} were added in the solutions of NaCl. Then the solutions were evaporated at 80 ^{0}C in oven for about 4-5 days. The recrystallised residue were normally crushed to powder and heated at 500^{0}C in fabricated furnace for 1 hr and quenched. Analytical reagent grade chemicals, sodium chloride and dysprosium chloride (hydrate) were used in present investigation. The samples were exposed to a γ-dose from ^{60}Co source having a dose rate of 0.50 kGy/hr. Thermoluminescence were studied with PC based Thermoluminescence analyzer (1009 I) system set-up. Glow curve were recorded by heating 1 mg sample in temperature range 10 to 300 ^{0}C with constant rate of 10 ^{0}C/min. All experiments were performed in identical conditions and it is observed that the results are reproducible.

RESULTS AND DISCUSSIONS

Thermoluminescence glow curves

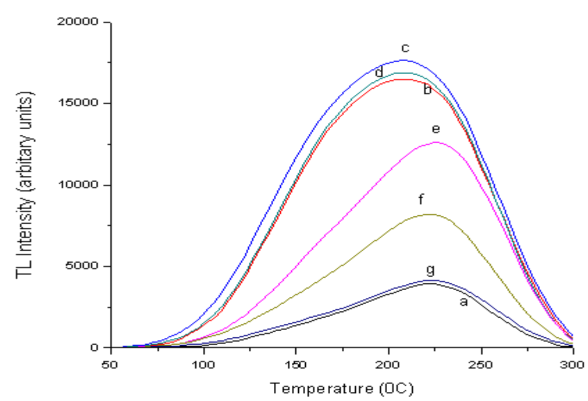

Figure 1. TL glow curve of NaCl (pure) and $NaCl:Dy^{3+}$ (0.05-0.5 mol%).exposed to gamma-dose = 0.50 kGy.
(a)NaCl (pure), (b)$NaCl:Dy^{3+}$ (0.05 mol%), (c)$NaCl:Dy^{3+}$ (0.1 mol%), (d)$NaCl:Dy^{3+}$ (0.2 mol%), (e)$NaCl:Dy^{3+}$ (0.3 mol%), (f)$NaCl:Dy^{3+}$ (0.4 mol%), and (g)$NaCl:Dy^{3+}$ (0.5 mol%).

Figure 1 shows typical thermoluminescence glow curves of NaCl (pure) and NaCl:Dy. An isolated single peak is observed due to only one type of luminescence centre is formed during irradiation by γ-rays in each sample. For $NaCl:Dy^{3+}$ (0.1 mol%) the increase in TL intensity is about four times more than pure NaCl material. For NaCl (Pure) and higher concentrations (0.3 to 0.5 mol%) of Dy^{3+} doped in host materials the temperature of TL peak intensity is remained same around 220^{0}C and for other low concentrations (0.05 to 0.2 mol%) of Dy^{3+} doped in NaCl it remained same and is around 216^{0}C. This may be due to change of phase in low concentrations (0.05 to 0.2 mol%) of Dy^{3+} doped in NaCl samples. But the change in temperature of peak height of thermoluminescence is less and can account to be negligible.

Effect of dopant concentrations on TL intensity:

Dependence of TL intensity with different concentrations of Dy^{3+} doped in NaCl is shown in Figure 2. The TL intensity is found to be saturated at 0.1 mol% of Dy^{3+} doped in NaCl material out of the prepared samples and then it decreases with increase in concentrations of Dy^{3+} in NaCl. Low concentration of impurity ions shows the maximum intensity, is a good sign for the development of materials for radiation dosimetry in terms of cost of the material.

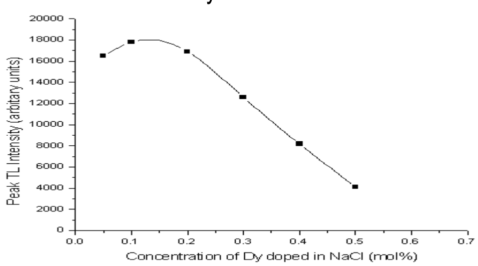

Fig 2. Variation of Peak TL Intensity with different concentration of Dy^{3+} doped in NaCl, exposed to gamma-dose = 0.50 kGy

Dependence of TL on radiation dose

Figure 3 shows the dose response of TL intensity of NaCl:Dy^{3+} (0.1 mol% and 0.2 mol%) samples. The TL intensity increases with the γ-rays exposure upto 0.5 kGy and then it becomes saturated after 0.5 kGy γ-rays exposure in both the materials. This is due to, when alkali halide crystal is exposed to high energy radiation like γ-rays or x-rays; excitation of electrons of halides atoms from valence band to conduction band takes place. Some of the excited electrons return immediately from the conduction band to the valence band; however some of the electrons in the conduction band get trapped in the negative ion vacancies during their movement and consequently the formation of colour centres takes place. Initially the number of colour centres increases with the radiation doses given to the crystals and thereby, the luminescence intensity increases with the radiation dose. However for long duration of the irradiation of the crystals the recombination between electrons and holes takes place and consequently the density of colour centres in the crystals attains a saturation value. In fact, the luminescence intensity attains a saturation value for high radiation doses given to the crystallites [6].

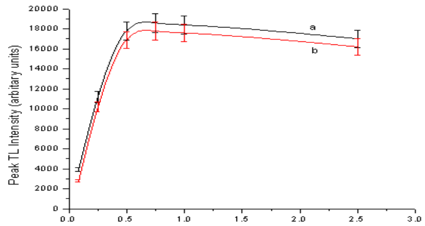

Fig 3. Variation of Peak TL with different gamma exposure of (a)NaCl:Dy^{3+} (0.1 mol%), (b)NaCl:Dy^{3+} (0.2 mol%)

Fading

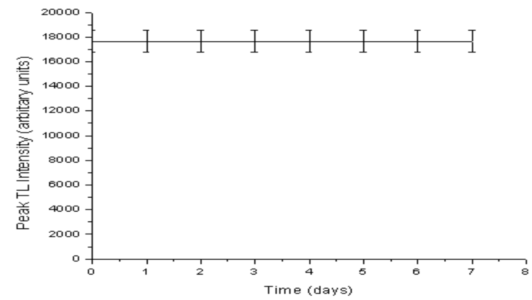

Fig 4. Effect of storage on the TL low peak in NaCl:Dy^{3+} (0.1 mol%), exposed to gamma dose = 0.50 kGy.

Figure 4 shows the effect of storage in dark at room temperature on the peak TL intensity in the NaCl:Dy^{3+} (0.1 mol%) sample. From this graph it is seen that the TL peak intensity of all the samples are quite stable since there is not much fading of intensities as the loss of colouration is less in darkness [7].

The measurement of ionizing radiation is a challenging task. The prepared NaCl:Dy^{3+} phosphor shows the dose measurement is possible upto 0.5 kGy gamma exposure using thermoluminescence technique, and has a negligible fading. Therefore the prepared phosphor may be useful for accidental radiation dosimetry.

CONCLUSIONS

Thermoluminescence in NaCl:Dy^{3+} material are reported. TL in these materials shows the single TL peak due to only one type luminescence centre is formed. The TL peak intensity is dependent on concentration of Dy^{3+} doping in the host material in all the samples. Similarly the peak intensity increases with γ-ray dose upto 0.5 kGy and then it becomes saturated after 0.5 kGy γ-rays exposure in all the materials.

The NaCl:Dy^{3+} (0.1mol%) sample have negligible fading on storage in TL intensity. These characteristics are shows the prepared NaCl:Dy^{3+} phosphors may be applicable for TL dosimetry for high dose measurement i. e. for the case of accidental radiation dosimetry.

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